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ABSTRACT

In the future, the requirements of industry will generate a wide range of hardware devices and software programs that will significantly alter and improve the quality of education. The driving forces behind the development of new technological devices include economics; emotional factors, e.g., the desire to develop aids for the handicapped; individual vision; international competition in military and other areas; and medicine, e.g., the development of computerized diagnostic systems based on artificial intelligence. Effective development requires an understanding of what is feasible, an interest in what is possible, and a vision of what is desirable. Successful competition in high technology requires managers who have technological understanding; business traditions and financial incentives that encourage long-range investments; a well-educated work force; committed engineers and scientists; and institutions that are organized and committed to research and development. There are many conditions that must be met if educational technology is to have a significant impact, including the allocation of resources for hardware and the development of educational software and courseware; training to use the new technologies effectively; and the development of authoring systems that are friendly, powerful, and affordable. Some new technological devices that will make important contributions to education include digital optical videodisks; image and voice devices; flat resolution computer screens; and digital computer networks. Those societies that most effectively solve today's and tomorrow's problems will have citizens raised to new levels of educational attainment. These new levels of attainment will be accomplished with significant assistance from the new technologies. (DJS)

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Technologies of the Future

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In the coming years, the requirements of industry will generate a wide range of hardware devices and software programs. These products will have the potential to significantly alter and improve the quality of education, but this will depend on several factors: allocation of resources for the hardware and the development of educational software and courseware; training to effectively use the new technologies; and development of authoring systems that are friendly, powerful and affordable.

Key words: Educational Technology, Future Technology, Technological Constraints, Courseware, Education, Training, Authoring Systems, Procedural Learning, Computers, New Technology, Technological Development, Computational Power, Videodisc



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1. Introduction

New technological devices and combinations of devices are being developed at a remarkable rate [15]. The rate limiting factors on the rate of development are human knowledge and ingenuity, and resource allocation. That is, we have reached the point in history that the opportunities for development are greater than we can possibly exploit at once. Therefore new devices are placed in a priority list for development by those who have the resources. Once resources are allocated, the drive, education, group dynamics, knowledge and skill of the development team determine how rapidly a new technology evolves to the successful prototype stage. Application is limited by the state of scientific knowledge, the state of technology needed for development, and the working environment of the development team. After a technology has been developed, its adoption and use depends on a skilled and well-managed force of industrial workers, marketing, price, and the resources and perceptions of potential purchasers [5,6,8,17,19].

Many of these devices, especially computer-related devices, image technologies such as the videodisc, and communications technologies have potential important applications to education [12]. The importance of these technologies, commonly called 'the new information technologies', lies in the fact that they dramatically reduce the cost of information and enable us to process information in fundamentally new ways - logically and inter-



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actively. Because of the obvious relationship between information and education, the new information devices challenge us to effectively apply them to education. However, for a variety of reasons, the task will be neither easy nor inexpensive.

Technological development – which new devices are actually developed and widely used – is inherently unpredictable because of the multiplicity of factors that determine the configuration and success of a new technological device or system [4,8]. In a classic case, in 1950 no one was in a position to predict the impact that the transistor would have on the exponential development of computer power. Social, emotional and political forces often shape the course of development and the diffusion of a technology throughout society and the rate at which a technology becomes available to the poor and middle class as well as the affluent.

It is intriguing to us that, like the two faces of some strange god, science and technology generate tension and anxiety in society. Through science we make more sense out of the mysterious and incomprehensible aspects of the world that surrounds us. Yet technology, because it is unpredictable in its nature and effects, continually brings new problems and puzzles [5].

The uncertainty of the direction of technological development is related to another refractory problem that educational as well as other systems face. This is the problem of when to standardize. The twin problems of premature standardization that inhibits innovation and too long delayed standardization that inhibits acceptance and market penetration of a new technology are kept in exquisite tension by the uncertainty of the technological future.

Just because a device is technologically feasible does not mean that it will be commercially produced. Once it is commercially produced and would be useful in education does not mean it will be available for education. To be available for education a device must (a) be reliable, durable, and inexpensive, (b) have educationally useful materials, and (c) be marketed over a period of years before a majority of schools has purchased the technology. Even then a new technological device may fall into disuse if it does not fit into the organizational traditions and structures of the schools.

We can think of five key transitions in the life

of a new technology or device: (1) The date the first prototype is produced proving technological feasibility, (2) the date the technology becomes commercially available, (3) the date the technology is used by 50% of the population, (4) the date of the first educational use of a technology, and (5) the date that the technology is extensively used by 50% of the schools or 50% of the students. The point is that the difference between date 1 and date 5 may be many decades. The prototype of the airplane was flown at the turn of the century, but by 1980 fifty percent of the people had not yet taken a commercial air flight.

The microcomputer prototype occurred in the late 1970s, but it is difficult to predict when most of the students in schools will have relatively free access to microcomputers. In this talk we will discuss many devices that are not yet cheap enough or otherwise presently available to schools. Our justification for this is that many presently expensive and exotic devices will become sufficiently common and available to schools and further, if we, as educators, are sufficiently aware of the potential of a device we may be able to accelerate the date at which it is used in education.

2. The Driving Forces for Development

We would like to make a few remarks about technology in general. Since education does not have the huge resources that are needed for a major technological development such as the videodisc or a new microchip, we must almost always make use of technologies that have been developed for other purposes – the military, medicine, commerce, and entertainment. Therefore, to predict the future of educational technology, we must understand the many forces that drive the development of new technologies in general. And, since all of the forces are accelerating as a result of the larger number of people involved in R & D and the increased flow of information, we can expect accelerated appearance of new devices and programs at a cost that will allow schools to consider their use.

Not surprisingly the promise and reality of economics plays a critical role. In a wide range of tasks such areas as payroll management, service scheduling, or automation, the new information technologies have resulted in dramatic economies.

The surplus wealth and death of old occupations of a technological revolution have always resulted in social disruption of work and living patterns and have necessitated a modification of the educational system and the curriculum. So the technologies have partly created the problems we face, have the potential to be part of the solution, and also have become significant objects of study.

In spite of the importance of economics as a driving force for development, it is not the only one. Each new technology builds upon existing technologies. Existing and new scientific knowledge helps to inspire the developer's imagination and define what is possible. Individual vision is an important factor [7]. Alan Kay of Atari conceived of a small powerful notebook size computer long before the technological foundations for such a device were in place. Today, Alan Kay's Dynabook is about to become a reality.

Emotional factors such as the desire to develop aids for the handicapped has attracted capital and led to novel machine human combinations. Symbiosis of humans and computers will probably evolve from this humanitarian effort.

International competition in military and other areas such as the space race, often generate the resources and the guiding vision for new technologies. For example, the complexity of modern weapons forces the military to be concerned with the use of new technologies to educate and train soldiers. The manuals for a new tank would fill the space inside the tank so that information compression through the videodisc is particularly appealing to the military. As a result the military is one of the principal supporters of R & D with the interactive or 'intelligent' videodisc. The very development of the microchip was fueled by the Americans' need for miniaturization in their rocket program since we did not have the powerful rockets the Russians had. Medicine is still another powerful force that influences and often leads to new information technologies. For example, the problem of medical diagnosis has attracted both resources and talent in the field of artificial intelligence.

The new technologies lead in two directions. On the one hand they promise to help us execute old tasks at less cost and in a more effective way. On the other hand they suddenly offer us the opportunity to do new things that we had not thought of before. In the process a pervasive new technology

changes our environment, our society, and us. This is certainly true in the case of education.

So we see that as computers become more and more central to the functioning of all aspects of society, a large array of new devices will steadily be produced which may be useful for educational purposes. Personally, we feel that it would be a wise investment to give educational R & D the resources to develop new technologies without depending upon hand-me-down devices from other sectors. The development of the PLATO system at the University of Illinois is a rare example in which this occurred.

3. Effective resource Allocation for Development

Effective development requires an understanding of what is feasible, an interest in what is possible, and a vision of what is desirable. This calls for managers who have technological understanding. Because of the lead time required for a major technological development such as the home videocassette recorder, we need business traditions and financial incentives that encourage long range investments - not short range profit seeking. In the United States this has been a major problem. Excellence in basic scientific knowledge does not assure technological supremacy. Great Britain has the highest per capita number of Nobel prizes, while Japan is relatively low on this scale. Yet Japan dominates international trade while Great Britain is having severe economic difficulties. Basic scientific knowledge, published in open journals, is a free international commodity. What is needed to compete in high technology (and what is lacking in the U.K.) is a work force that is well educated at all levels as well as engineers and scientists who are eager to keep up with the literature and convert fundamental findings into useful products.

Also needed are *institutions* that are organized and committed to development [3]. R & D by individual firms combined with industry wide R & D funded by private and government funds seems to be more effective than other models. Incentives that channel risk capital into new innovative firms, government subsidy policies that challenge industries to be competitive and modern, and an optimal level of competition are all strategies for keeping a country's firms on the cutting edge of technological development. An important, some-

times negative, factor in developed nations is the ability of special interests to either inhibit development by legal and regulatory delaying tactics or to increase the cost of innovation to the point that a firm may lose its ability to compete.

The above paragraphs are the context within which we see the development and deployment of educational technology taking place. We will now examine the educational technologies directly.

4. Present and Future Hardware Developments

We have, in the following discussion, picked the hardware elements that we believe can make an important contribution to education. We feel some discomfort in the hardware/software distinction since both hardware and software are often required to make a device of interest to education. With this apology, we will keep the distinction in order to impose some structure on the array.

4.1. Computational Power and Memory

The inexorable advance in computer power and the size of computer memories for a given price continues and probably will continue for at least this decade. This means that every two to three years the amount of computational power and memory one can buy for, say, \$1000 will more or less double. This in turn means that by the year 1993 we will, for the inflation adjusted equivalent of \$1000, have something like a 32 bit microprocessor and 4 megabytes of RAM (Random Access Memory). In addition we will have inexpensive special purpose microchips that can be used for special purposes such as graphics generation, managing communications, word processing, voice synthesis, voice recognition, etc., in parallel [10]. Not every bit of information will have to flow through the central processing unit (CPU). This should greatly speed up certain kinds of computations for which speed is critical such as voice recognition, file access, and graphics generation.

At the present time digital information is either dynamically held in solid state memory (i.e. power must always be on in order to avoid losing one's data) or it is recorded on magnetic films in the form of tape, floppy, or hard discs. The digital optical videodiscs in development have the potential for a gigabyte of memory that is 'read' by a

laser beam. Advances in the technology developed here at Philips-Eindhoven and elsewhere [23] will result in a commercial product that will enable us to record, erase, and, of course, optically detect or 'read' digital information. This will enable us to store, inexpensively and in a small space, huge reference libraries, spoken passages, and picture collections for educational purposes [11,22].

However, the optical videodisc has a rapidly moving disc and the disc and the laser beam must move relative to each other to read a particular portion of the recorded information. Moving parts are subject to breakdown. It would be desirable to have an inexpensive, large memory capacity medium that can be used without moving mechanical parts and which does not require a power source in order to retain the memory trace. In other words, we would like an inexpensive non-volatile addressable memory. At present the leading candidate for this is the magnetic bubble memory. Intel Corporation has announced a 4 megabit (approximately half a million characters) bubble memory. Withing two years the cost of this memory is projected to be \$200 [21]. With a memory of this size and cost, the very powerful, notebook-sized computer dreamed of by Alan Kay will become common.

It seems that there will be a place for both optical and bubble memories. The optical medium will be particularly useful for text files and other forms of information (voice, music, pictures) where an occasional error is less catastrophic than in program files.

4.2. Image and Voice Devices; Importance and Relation to Memory

We believe that in the future the computational power of the computer will be combined with various media to provide random access to images and voice passages and also to provide an intelligent interpretation of a student's response to a picture or message. Therefore in the following discussion we will always assume that we are talking about media under computer control. (Eventually, if computer memories become great enough we will need no media except those that display the results of a computer operation). Inexpensive and accessible images combined with computer logic will have a great impact on the learning of concepts, processes, and procedures.

The optical videodisc has reduced the cost of a color image to about 0.05 cents or 20 images per penny. In digital form the optical disc technology can deliver about 100 to 200 hours of spoken text. At the present time one cannot easily have spoken messages with a still image from a videodisc. Within about a year we will be able to capture an image from a videodisc and hold it on a screen while the laser beam goes to another portion of the disc and plays a relevant sound/speech passage. Alternatively, we can capture the code for a speech passage in computer memory and recreate a spoken passage while the laser plays one or more images onto the screen. The ability to create a spoken passage simultaneously with the display of a single videodisc ('still') frame is called sound-over-still. Sound-over-still will greatly increase the information capacity of the videodisc for instructional purposes.

The optical digital videodisc can also serve as a huge reservoir of computer programs that can be loaded into the computer when needed. A credit card-sized optical memory is under development that will hold about 2 million megabytes [11]. This would hold many large educational computer programs, over 200,000 words of text, 32 video pictures, or a combination of these. The result is that one could carry in one's coat pocket a large library. Together with the portable computer, the compact digital optical memory will deliver time-free, space-free learning for much of the curriculum.

It is difficult to predict what the future capacity of optical memories will be. A limiting factor is the wave length of the light used to create the master disc. If we cut the wavelength in half, we can quadruple the density of the 'pits' used to encode the information. If we use electron beams as in electron microscopes, we can conceivably have discs with 10,000 times as much information on a single disc as today's videodiscs. A reasonable number of discs could preserve the entire contents of a national library. We would expect information compression of this order in some technology by the end of the century.

Once complex images can be stored in huge memories, they can be manipulated by computer programs in all sorts of ways. The educational possibilities of simulations of realistic complex environments such as the interior of a computer or a jet engine are exciting.

4.3. Large, Flat, High Resolution Color Screens

Most computer screens today are cathode ray tubes (CRTs – similar to television picture tubes). They are large and bulky. They are easily damaged, require large amounts of power and inhibit portability. Attractive, high resolution screens are expensive and the software required to give one the aesthetic sense comparable to a well-printed book is complex and expensive. But the transition to large, flat, high resolution color screens seems inevitable and is occurring [16]. Casio has produced a 2.5 inch flat LCD TV screen. Radio Shack is marketing a notebook-size computer with a large liquid crystal screen that displays 8 lines of 40 characters. Surely it won't be too long before a full page flat screen is available for portable computers.

Arrays of flat screens will allow one to refer to different parts of documents while composing a paper, a commentary on a document, an analysis of a detailed structure, etc. Very large wall size flat high resolution screens will be useful for art, science, and technology – wherever large detailed drawings or pictures are needed. Sophisticated graphics and programs will give one a sense of location and ease of movement within a document or program as well as the ability to quickly call up glossary definitions, pictures of unfamiliar objects, alternative explanations of a difficult principle, etc.

Touch sensitive screens allow very young children to interact easily with visual objects. Voice recognition combined with touch screens or sensors that identify where one is pointing can give one an eerie sense of mastery of a complex environment. Many of these effects can be seen in R & D laboratories. Some of the most dramatic demonstrations are those of the Machine Architecture Group of MIT.

4.4. Printers, Plotters, and Hard Copy

Often print on paper or the modern equivalent of print on paper is needed or desired. The need for hard copy printouts of computer files and computer graphics has stimulated innovation in low-cost, high-quality printers and plotters. There is potential for truly low-cost printers that schools can afford in laser printing technology [9]. Since many users can share a single high quality printer,

a reliable computer-controlled laser or ink-jet printer at a cost of about \$1000 or less would be affordable, reliable, durable, fast and aesthetically pleasing. Programs could adjust the print style, size and (sooner or later) color of the printed material.

4.5. Digital Computer Networks

Networks have the potential to supply elements that are often missing from computer-based education. Those elements are access to large centralized libraries and databases, conversation with a teacher or mentor for isolated students, sharing of ideas and problems with a scattered network of people who share a common interest. The general point is that communication can complement computer lessons by connecting the individual lesson to the wider world. Without the context of conversation and reading the student may find it difficult to see the relevance of his/her school work.

Laser diodes and fiber optics are turning the telephone network into a huge digital network. Cable TV systems are developing the technology for two-way communication between subscribers and a central computer. Communications satellites are becoming so powerful that they may someday handle low-cost point to point (school to school, school to library, and even person to person) digital communication. Sophisticated networks are being designed. The key element for education will be the cost. Unless the cost decreases greatly or special rates are provided for educational purposes, this valuable technology will be largely absent from the schools.

4.6. Input Devices: Voice, Optical Character Readers

It is surprising how much difference the right interface makes. When one is making selections and can touch the screen instead of typing characters, the whole interactive process seems to speed up and come alive. With an orientation detector attached to a forearm and a penlight to show where one is pointing, one can manipulate objects on a computer screen from a distance of several feet. An increasing array of input devices will be available in the years to come. Two are of particular interest: voice input and optical character recognition.

It is obviously difficult for a computer to recognize natural human speech. At the present time, a \$3000 voice recognition device can recognize about 200 carefully spoken and enunciated words. The difficulty in natural speech recognition arises partly from the great variability in speech. Individual voices vary greatly in accent, dialect, pitch, speed, etc. The greater difficulty in computer recognition of speech arises from the fact that humans use a great deal of their intelligence in understanding rapid natural speech. We use our general knowledge of the world to predict what words are coming next so that we only need to confirm or correct as a person speaks. As a result natural voice recognition by computer will probably require significant advances in artificial intelligence representations of real life situations that provide the context for speech.

In spite of (or possibly because of) its difficulty, much research is taking place in voice recognition because of the potentially huge economic returns. Millions of secretaries are paid billions of dollars a year (about 15 billion dollars per year) to transcribe human speech. A voice recognition device that immediately displayed human speech on a computer screen would result in a huge increase in efficiency. For children the combination of voice recognition, voice synthesis, word processing, and text analysis programs has the potential of greatly facilitating the acquisition of literacy and the use of language to develop and communicate ideas. Imagine the excitement of a young child telling a story and seeing her words appear on a computer screen. Then imagine all the educational activities that could take off from that point.

Optical Character Recognition is vital for the creation of personal and public files and for making our libraries of printed documents accessible to computer search. I have a moderate size set of carefully selected books and files of journal articles and other documents. I would like to have much of this on some form of digital memory so that I could use the computer to search for and comment on the material. At the present time the only way this could be done would be to retype the material into the computer. It would take even a good secretary months of mind-numbing work. To capture the world's knowledge for the computer we need ways of automating the process.

The Optical Character Reader is a good example of the serendipitous sharing of technological

advance. The Kurzweil Optical Reader was invented by an MIT graduate student to help blind people. It is one of the best and the most expensive optical character readers because its program enables it to interpret almost any type of font. It will not be too long before the character reader will be able to interpret even handwritten material although this will, as in the case of speech recognition, require a fair degree of machine intelligence. At any rate, we predict that once Optical Character Readers are widespread they will become one of the most useful devices for education and we will wonder how we ever survived without them.

4.7. Other Devices

Special programs provide the opportunity for students to engage in creative effort using the knowledge and skill they have learned. These include programs such as word processing, computer graphics, animation programs, computer 'painting' programs, planning programs such as Visicalc, programs that help music composition, structural analysis programs, programs that assist in the planning of experiments, etc. These are important because we believe that the challenge and opportunity to engage in creative activity serves two major purposes: First, the knowledge and skills used in creative activity are moved into a class of skills that have been used and useful. As much learning as possible should be integrated into this class. Second, the difficulties one has in carrying out a creative task serve as a challenge to learn more. This makes the organized instruction of the classroom more relevant. Thus programs that encourage and assist students of all ages to write stories, paint electronic pictures, write music, design objects, analyze structures, plan experiments, etc., will, we believe, make one of the most important contributions to education.

4.8. Writer's Workbench

Investigators at the Bell Telephone Laboratories have created a sophisticated set of programs called the Writer's Workbench. These programs analyze text passages for a variety of characteristics such as the use of active vs. passive voice, repetitious usage, sentence length, reading difficulty, inconsistent use of tense, and other bad grammatical practices. Another program compares

the style of a passage to the style of famous writers such as Ernest Hemmingway and Faulkner. The original purpose of the Workbench was to assure that an 8th grader could read Bell Telephone documents. However, the programs have been so useful that staff throughout the Bell system use the Workbench to help improve the quality of their writing. The program analyzes and reports but never forces the author to make a change. There is anecdotal evidence that use of the programs sensitizes one to elements of good practice and that the quality of writing improves with time.

4.9. Robots

Programming a computer to execute an assigned operation or an operation of one's own choosing can be useful in developing the executive skills for problem solving. The idea is to have the student learn by teaching the computer [20]. The robot is in many ways merely an enhanced computer because of the range of information it can accept and the range of actions it can perform. The language and procedures that must be learned in order to control the robot can be adjusted to the level of the student. In general, the opportunity and challenge of learning to control a powerful instrument provides strong incentive and motivation for most people. Having children learn by teaching robots is an interesting example.

4.10. Three Dimensional Computer Objects

In science fiction and now in reality robots are being designed that can be directly manipulated by humans who sit at a distance from the computer. The first example of this was the WALDO, a set of hands that are used in radioactive environments. Video enables the operator to see the objects to be picked up. The operator puts on a pair of gloves with servomotors that enable him/her to feel objects touched by the mechanical hands in the radioactive environment. Pressure sensors in the mechanical hands transmit information to the gloves. Thus when the mechanical hands encounter resistance, the human feels resistance in the gloves. When the human moves the gloves, the mechanical hands move. Obviously, the strength of the mechanical hands need have no relation to human strength. Thus, humans can be given large mechanical advantages for many tasks while retaining the human sense of touch.

Michael Noll [14] is a computer scientist who invented a novel device for his graduate thesis in electric engineering. He put the coordinates of the surface of three dimensional objects such as cubes and spheres into the data files of a computer. These coordinates were used to control a stylus. If one picked up the stylus and approached the coordinates of the surface of the cube, the stylus would behave as if it had touched the cube, i.e., the servomotors would prevent the stylus from penetrating the surface – just as if the stylus had hit the surface of a real cube. By the touch of a key, the computer defined object would be changed. Also, the mechanical properties of the computer object could be changed from steel to foam rubber. Thus, with this type of device one could 'feel' objects that exist only in the data files of a computer. Instead of the stylus we could use the gloves of the WALDO. Computer graphics can display the imaginary objects on a screen so that one would have most of the sensation of manipulating real objects. We can imagine a variety of educational activities that would make use of this way of simulating three dimensional objects. Whether the activities were useful or trivial would depend on the assignments made, the tasks undertaken, and the questions asked.

5. Conditions for Educational Technology to Have a Positive Effect

5.1. Role of the Government

There are many conditions that must be met if educational technology is to have a significant positive effect on education.

Resources must be allocated to assure the availability of hardware, software, and courseware. Decisions must be made regarding the choice of equipment, and plans should try to account for future developments. People must be trained to produce excellent materials and to use the technology properly. Organizational structure and practices must be modified to help people be productive with the new technologies. Steps should be taken to assure important as opposed to trivial uses of the technology and it is not always easy to know the difference. We must increase our understanding of how and why people learn while we continually modify our ideas of what knowledge is

most worth having. At every step justifiable skepticism and entrenched practice oppose innovation while the tendency to adopt educational fads often shoves us too rapidly in false directions. All in all we face an intimidating set of tasks – associated with so important a matter as a nation's education.

Educational technology, to have an impact on education, must first be available to schools and students. For the equipment to be available money and other resources must be allocated for the acquisition of the hardware. Particularly in the case of technologies like the computer and the computer-controlled videodisc, the schools in the United States are faced with a serious problem. In the United States education is highly decentralized. As a result each school district is free to purchase whatever equipment and course materials it wishes (Some states do have state-wide adoption for textbooks, but this is not yet the case for computers and computer course materials.).

The fact that both equipment and course materials are sold largely by commercial firms generates a problem. Initially there are no course materials for a new technology. The schools say, "Why should we buy expensive equipment when there is no adequate supply of course materials for the new equipment? If you can guarantee a supply of excellent materials, we will consider a purchase". The equipment manufacturers say, "Course materials are not our business. Go see the publishers". The publishers say, "Look, if there were an installed base of equipment we could justify the investment required for course development. But we are the small end of this business. We cannot afford to invest in courses for a particular piece of equipment before we know that it will be widely used". As a result, the use of a new technology is often delayed until somehow the impasse is broken. We propose that in a situation where the market forces cannot operate effectively, the government has a proper role to play even in a country as suspicious of federal action as the U.S. As a matter of fact, we are subsidizing the donation of equipment to schools by tax incentives to manufacturing companies.

5.2. Software and Courseware

We make the distinction between courseware and software because many educationally useful programs such as word processor programs would

not normally be called courseware. Much software provides intellectual tools and requires large sums of money and talent for development. We feel that the educational community should be more aware of this dimension and support the development of software related to education. LOGO is an example of such development and even in this case the support was comparatively niggardly in our judgement.

For effective development of software and courseware, centers such as COI (Centre for Education and Information Technology) are essential. While small scale efforts for course material development should be encouraged as a way of finding and encouraging new talent, the record of such cottage efforts in the field of education is not impressive. Government-supported centers for development have performed reasonably well. They supply a critical mass of talent and equipment with access to students [18]. The Open University of Great Britain is an example of such a center and there are several others in Europe. For stability such centers should have a source of funds that is not sensitive to year to year political tides. We recommend that a small tax for educational development be attached to the sale of information technology equipment and on the flow of information. The proceeds of these two taxes should be put into a fund for educational software and courseware development. This fund would support centers as well as small grants for new techers and others who want to enter the field.

Much instruction requires or can greatly benefit from photographically realistic images (e.g., biology, surgical procedures, etc.). It is now feasible to make compact easily accessible electronic archives of images using the videodisc [2]. These images can be accessed by computer, distributed electronically, and edited into new configurations quickly and at relatively low cost once the equipment and protocols are in place. We recommend that educational development centers be given the task of forming such archives of images and arranging for relatively free access to these archives by all certified educational institutions in all nations. The combined computer data and image files will one day form the basis of what has been called the World Brain. Educational development centers should take the lead in assuring that schools have access to and can afford the information of the world.

One of the most difficult situations arises when an educational system slides into mediocrity. The United States, as clearly stated in a recent Federal Committee report [1] has been wrestling with this question for at least the last twenty years. As a result, we should take every precaution to assure that the educational development centers adopt a tradition of innovation and the highest standards for excellence in the talent recruited and the products of their work.

It is important for a development center to have unquestioned access to students to try out new procedures, structures, and curriculum materials. Since the learning time of students is valuable and cannot be regained once used, the rules for access to students should be carefully considered.

5.5. *Training of Scholars and Teachers*

We believe that people should be educated to produce instructional materials for the new information technologies such as the computer, and the videodisc. A great many skills, extensive knowledge of the subject being taught, and knowledge of the learning process are required for excellent results. In the absence of properly educated developers, the component skills must be assembled by hiring people who have the parts but no sense of the whole. This conventional 'team' approach is expensive and often generates tensions that interfere with effective development. When teams must be used, we propose that the team leader – the equivalent of the motion picture producer/director – should be the person who has the education, experience, and authority to see the whole and to integrate the diverse talents of team members [13].

We propose that an essential foundation for an educational developer is extensive knowledge of the subject being taught. The reason for this is that the structure of knowledge in a discipline should strongly influence what is taught, when it is taught, and how it is represented. However, a complementary skill is needed – knowledge of how students learn.

Only when educational research investigators, educational developers, and teachers have an equivalent education, similar standards, and a working research, development, and practice network, – only then will we be able to effectively exploit new information technologies.

Who should train the educational developers?

We propose new organizational entities whose offerings combine knowledge of cognitive science, knowledge of the subject being taught, and a commitment to research and development. In the United States we have had difficulty forming permanent structures of the kind needed.

Two promising examples that we are familiar with were started about ten years ago but are presently having difficulty in maintaining their vitality. The SESAME program of the University of California at Berkeley offers a doctoral degree in Science and Math education (e.g., a Ph.D. in Physics Education). The University of Illinois at Chicago Circle offers a Doctor of Arts degree in the subjects of Mathematics, Physics, Biology, and Chemistry. Faculty and students of both programs are strongly related to the subject matter departments, and both programs emphasize research into the learning process and the development of instructional materials. Unfortunately, in spite of evidence of effectiveness, the traditional faculty have not helped the programs to grow in the past (there are some indications that attitudes may be changing).

What should be learned? In a recent paper [13] we suggest that future developers become proficient in the following areas: Subject knowledge, knowledge of knowledge structures, knowledge of the learning process, knowledge of form and style of communication, knowledge of production tools (e.g. TV studio equipment), and knowledge of research methods and results. Any one of these areas is often sufficient for a course of study. As in the case of medicine in the United States, future developers should make an early commitment and work hard to achieve the breadth and depth required.

5.4. Development of Authoring Systems

At the present time producing instructional materials for the new information technologies is extremely labor intensive. For example, producing a videodisc requires many different pieces of equipment, each with its own standards, timing, codes, formats, procedures, etc. Usually a different technician has mastered the intricacies of each piece of recording, reproducing and editing equipment. When an instructional developer communicates with each person, the unfamiliar restrictions

(e.g. the script has to be in a particular format) cause delays and/or distortions of the developer's intent.

It is our judgement that an instructional development center could properly invest in the development of an integrated authoring system that would permit an author to compose a course of materials from a single integrated computer-controlled, menu-driven master console. With today's technology and programs the console could be made friendly, powerful, and affordable. Video tape, motion pictures, slides, printed pictures, computer generated graphics and text, audio recordings, video camera signals, computer programs (e.g. word processors, graphics editors, logic menus for lesson construction, etc.) could all be orchestrated by a single author with perhaps one extra person for technical help. Word processors, graphics editors, logic menus for lesson construction, and other programs would all be available as intellectual tools for authors. From our experience such an authoring studio would both decrease the cost of development and increase quality as individuals become skilled in its use.

Such a system should permit a local teacher or curriculum expert to easily modify centrally produced materials. This property would increase the acceptance of new materials. Materials could be modified to capitalize on local conditions (e.g. local flora, fauna, economy, climate), new and timely information, and local priorities. Once again, a menu-driven computer-controlled system allows a relative novice to do this. An example is the WISE authoring system developed specifically to facilitate the development and revision process. The general point is that we have hardly used the technology to make the instructional authoring process more efficient and effective.

We agree with most experts in believing that the computer used in the development system should be considerably more powerful than the computer needed to deliver instruction to students. There are two reasons for this. One is that the rate of increase of computer power is so great that only by developing on high-powered computers can the results more closely match the computers that will be available at the end of the development process. The second reason is that once a program has been written, it is usually comparatively easy to modify it to run on a less powerful computer. The result is a more elegant final product than if the author is

constrained by an underpowered computer from the start.

Computers can be used for trivial as well as important activities. The development of knowledge and intellectual skill can be exciting, but at some level it is intrinsically difficult. As the number of variables to be dealt with becomes greater, as the problems become more difficult, as the competition becomes stiffer, a strong ideologic commitment to learning supports the efforts of the individual student. Ritual and tradition help to symbolize that commitment. Since the new information technologies tend to break down the old traditions, the designer of the new educational environment has the task of creating new rituals and traditions based on the nature of the new technologies.

There is a dilemma in this. Our society shows a trend toward more individual choice and freedom. Yet the evidence from the United States is that freedom in school results in the choice of courses that avoid the hard subjects and the discipline for optimal intellectual growth. On the other hand too much control results in avoidance of individual responsibility. The tension between these can, we believe, be managed by a variety of institutional strategies. One is to have a well defined compulsory curriculum in which the electives are more demanding than the compulsory courses so that the students are challenged. Another is to give students assignments involving creative effort using the knowledge and skill they have. The nature of the assignments would and should vary in the freedom offered to the student (e.g. design an experiment involving statistical analysis of results, make a container to protect an egg when dropped from the fifth floor, debate the following question, make up and debate a question, make a computer art image working with another person who composes on the same screen as yourself, compose a play, design an arch using some everyday object that is discarded by society, etc. etc.).

Each new technology such as communication networks, videodiscs, and computers offers a new constellation of potential activities, experiences, and subjects. These experiences interact with the process of psychological growth. Unless we understand both psychological growth and the intrinsic psychological and educational effects of a technology, we run the risk of making serious errors in the use of a new technology. At the least we may fail

to make the best use and at the worst we may cause damage. Therefore, we propose that a center such as this one engage in a serious research effort to understand the nature of the interaction between humans and information in its various guises.

Consider some of the apparent contrasting properties of humans as teachers and of computer-based education. If these statements are not self-evident on the basis of present knowledge, consider them hypotheses. Humans tend to stereotype people and form dominance chains. The computer shows no such characteristic, taking each response afresh and not judging it on the basis of the status of the individual in society. Humans tend to be impatient while computers are infinitely patient. Humans tend to test the constraints of a system and try to negotiate with other humans. The computer is immune to such negotiation in most cases (except for the computer hacker who becomes so proficient that he/she can alter the program). The teacher often wants to be in control. The computer can be programmed to become a manipulable world within the constraints of the operating system. Much human teaching takes a lecture/fact approach whereas computers can be configured to teach procedures via simulation of a wide variety of processes (e.g. flying an airplane, repairing a machine, running a power plant). Humans depend upon verbal representations because of the cost and difficulty of producing images on demand (e.g. this paper). Computers of the future will give us rich access to images, graphical displays, and pictures of processes.

On the side of humanity, humans are extremely good at pattern recognition whereas present day computers are extremely limited in this. Humans have a vast associative intelligence that allows them to engage in a rich conversation, interpret non-standard information, and make intuitive and inductive leaps. Machine intelligence in these domains is very limited at present. A colleague reported this quote of an 8-year old girl: "A computer is a machine that gives simple answers to complicated questions." Humans have a vast reconstructive memory for events, images, models of the world and parts of the world. We have rules for reconstructing memories on the basis of limited information using schema whereas present computer memories are literal.

6. Procedural Learning

Formal education has difficulty teaching procedural skills (e.g. glass blowing, laboratory procedures, methods of analysis, problem solving) as opposed to declarative knowledge (facts and statements). This is the distinction between knowing how vs. knowing what. Procedural skills are difficult because they often involve expensive equipment (e.g. microscopes), take much human attention to the details of human performance (e.g. coaching a psychomotor skill), and require a rich supply of motion pictures (e.g., slow motion video of a process or skill). Sometimes procedural skills involve danger to the student and are therefore delayed until an advanced stage of education (e.g., flying an airplane).

The combination of the videodisc and the computer permits us to eliminate most (but not yet all) of these limitations to the incorporation of procedural learning objectives into the curriculum. The computer is a logical device that can manage a very large number of if...then...relationships. As a result the construction of educational simulations is a natural outgrowth of the intrinsic nature of the computer as a medium. At present most computer simulations are limited in their graphics because of memory limitations (as well as by authoring limitations, since developing simulation relationships is a demanding task). However, the videodisc under computer control can partially compensate for this limitation and provide simulations of many events and processes that require a rich supply of images. We expect that a major effect of the computer in education will be the infusion of procedural skills into the curriculum.

There is evidence that the opportunity to observe models of skilled performance (e.g., watching a skilled violinist or surgeon) facilitates the learning of that performance although it does not, in itself, 'teach'. The videodisc with its capability for slow motion and frame by frame analysis of an action is an important advance for the display of skilled operations. It has been suggested that the image capacity of the videodisc can be used with the computer to teach interpersonal skills through the simulation of person to person situations. What is more problematic is the extent to which we can make visible and model such internal operations as problem solving, planning, thinking of a good question, etc.

We would like to restate the value of human-to-human communication as a way of stimulating and acquiring new ideas, placing computer lessons in the context of one's world view, and making specific connections between skills acquired in computer lessons and events where they may be applied.

7. Summary and Conclusion

The computer and other technologies cannot yet make an unwilling student learn and cannot compensate for a mediocre and disinterested attitude on the part of a community. But if there is the spark of interest in acquiring knowledge and skill, if there is commitment to academic and intellectual achievement, then the new information technologies have the potential for truly transforming the educational experience for the better. So many forces and so many talented people are at work developing new technologies that we are facing a tidal wave of information, logic, image, and communication devices of incredible elegance and power. To wisely use the new technologies will require heroic efforts by individuals and the collective efforts of society. The future belongs to those who rise to the challenge and the opportunity. Those societies that most effectively solve today's and tomorrow's problems will have citizens raised to new levels of educational attainment. These new levels of attainment will be accomplished with significant assistance from the new technologies we see around us, those we only dream of, and those that will make life ever more surprising.

References

- [1] *A nation at risk: The imperative for educational reform*; A report to the Nation and the Secretary of Education by The National Commission on Excellence in Education; April, 1983. Washington, D.C., Supt. of Documents, 1983.
- [2] Bunderson, C. Victor, A.O., Baillio, B., Olsen, J.B., Lipton, J.I., and Fisher, K.M. Instructional effectiveness of an intelligent videodisc in biology. *Machine Mediated Learning* 1 (1983), in press.
- [3] Carter, Sir Charles, Conditions for the successful use of science. *Science* 219 (1983) nr. 4590, 18 March, p. 1295-1298.
- [4] Clarke, Arthur C., The 90s - The future city is not Manhattan but Disney World. *Chicago Tribune Magazine*, Nov. 26, 1972, p. 108.

- [5] Drucker, Peter F., Silent revolutions. Unpublished paper, about 1980.
- [6] Evans, Christopher, *The Micro Millenium*. New York Pocket Books, 1979.
- [7] Foster, Richard N., A call for vision in managing technology. *Business Week*, May 24, 1982, p. 24.
- [8] Gomory, Ralph E. Technology development. *Science* 220 (1983) nr. 4597, 6 May, p. 576-580.
- [9] Jones, Edward, Future computers. *Popular Computing* (1983) nr. 7, May, p. 136.
- [10] Kinnucan, Paul, Artificial intelligence: making computers smarter. *High Technology* 3 (1982) Nov./Dec., p. 60.
- [11] Lemmons, Phil., The software revolution: where will we store all those programs? *Byte B* (1983) nr. 3, p. 6.
- [12] Licklider, J.C.R., Social and economic impacts of information technology on education. In: *Hearings on secondary math and science education before the subcommittee on Science Research and Technology*; 97th Congress, May 7, 1982, nr. 169. Washington, U.S. Govt. Printing Office, 1983.
- [13] Lipson, Joseph I., Fisher, Kathleen M., The making of Michaelangelos: educating instructional designers for the new electronic technologies; commissioned paper for National Institute of Education Conference on Courseware Portability, Pittsburgh Pa., June 25-26, 1982.
- [14] Noll, A.M., Man-machine tactile communication. *SID Journal* 1 (1972) nr. 2, July/August, p. 5-11.
- [15] Platt, John, The acceleration of evolution. *The Futurist* 15 (1981), Feb., p. 14.
- [16] Posa, John G., Flat display merges technologies. *High Technology* 4 (1983), May.
- [17] Press, Frank, Maintaining scientific primacy; [Editorial]. *Science* 220 (1983) nr. 4597, 6 May, p. 559.
- [18] Reif, Frederick, Personal communication. 1974.
- [19] Rosenberg, Nathan, *Incentives for innovation: technology and the economy*. Unpublished paper, about 1980.
- [20] Silverman, Stanley, Personal communication. May, 1983.
- [21] New techniques produce 4-megabit bubble. *Solutions* (1983), Jan./Feb., p. 13.
- [22] Vance, Vicki, Still frame audio debuts at NAB. *SONY Interactive Videodisc News*, Palo Alto, California, May, 1983.
- [23] Matsushita Electric unveils optical disk that erases; expects to start sales in '84. *Wall Street Journal* April 6, 1983, p. 12.